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(54) **Estimating the location of a mobile unit for emergency call assistance**

(57) The location of a mobile unit 20 (e.g. cellular telephone, 2-way pager) making an emergency call is estimated by measuring the signal strength received at a plurality of antennas linked to base stations. Each measurement is sent through network control to a computer. The computer forms a circle 30-33 around each antenna with radius derived from signal strength received at that antenna. The intersection points of the circles are used to define a small area in which the mobile is likely to be found. This area is communicated to an emergency assistance centre together with related information such as an area map. An operator at the centre can despatch rescue personnel and ask the emergency caller to confirm the location by identifying features which are shown on the area map. Steerable antennas may be used to provide vector locations and antennas unable to receive the signal may provide zone exclusion information. The mobile unit may use a command channel to report back signal strengths received from antennae. These received signals may be progressively decreased and the point of loss of contact used to determine distance from the antennae. If a caller has more than one type of mobile unit then both may be used to calculate a search area. The method may also be used to locate stolen objects.

Fig. 4

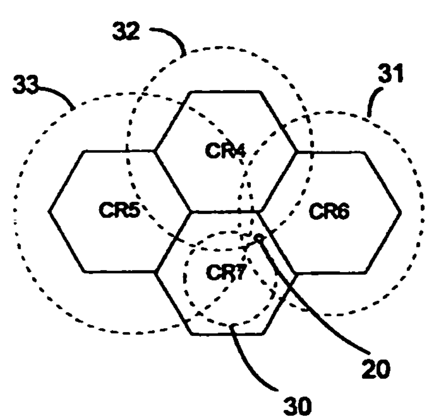

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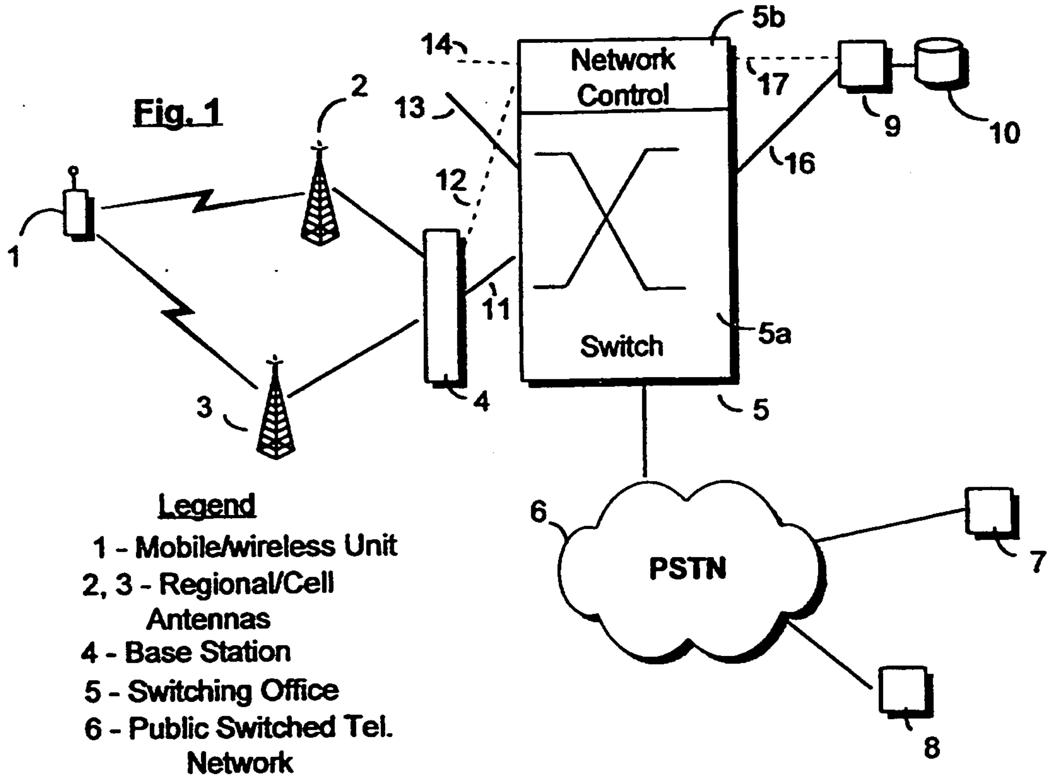
Fig. 1



Legend

1 - Mobile/wireless Unit
2, 3 - Regional/Cell Antennas
4 - Base Station
5 - Switching Office
6 - Public Switched Tel. Network
7,8 - Emergency (e.g. 911) Operators
9 - Controller/Computer
10 - Database (with details of cell geographic and other parameters)

Fig. 2

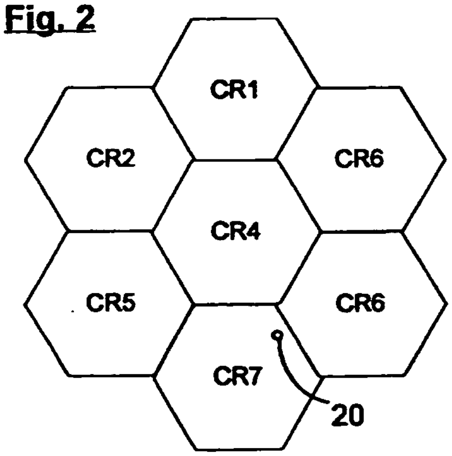


Fig. 3

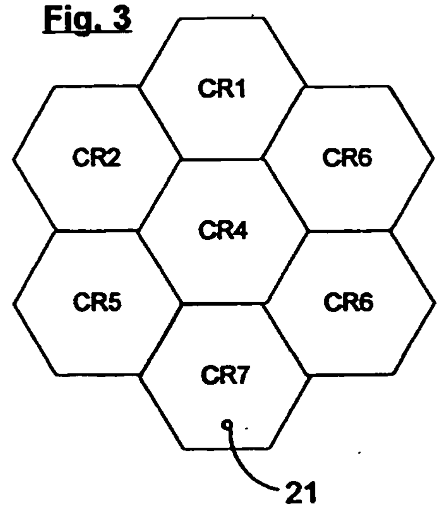


Fig. 4

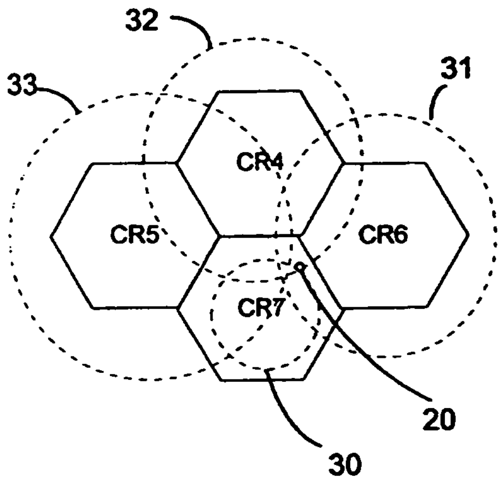


Fig. 5

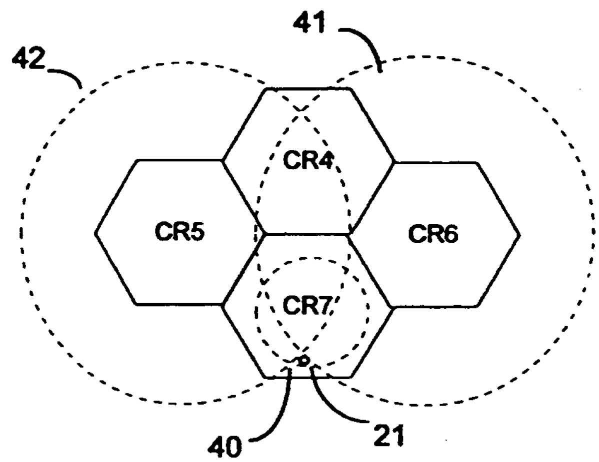
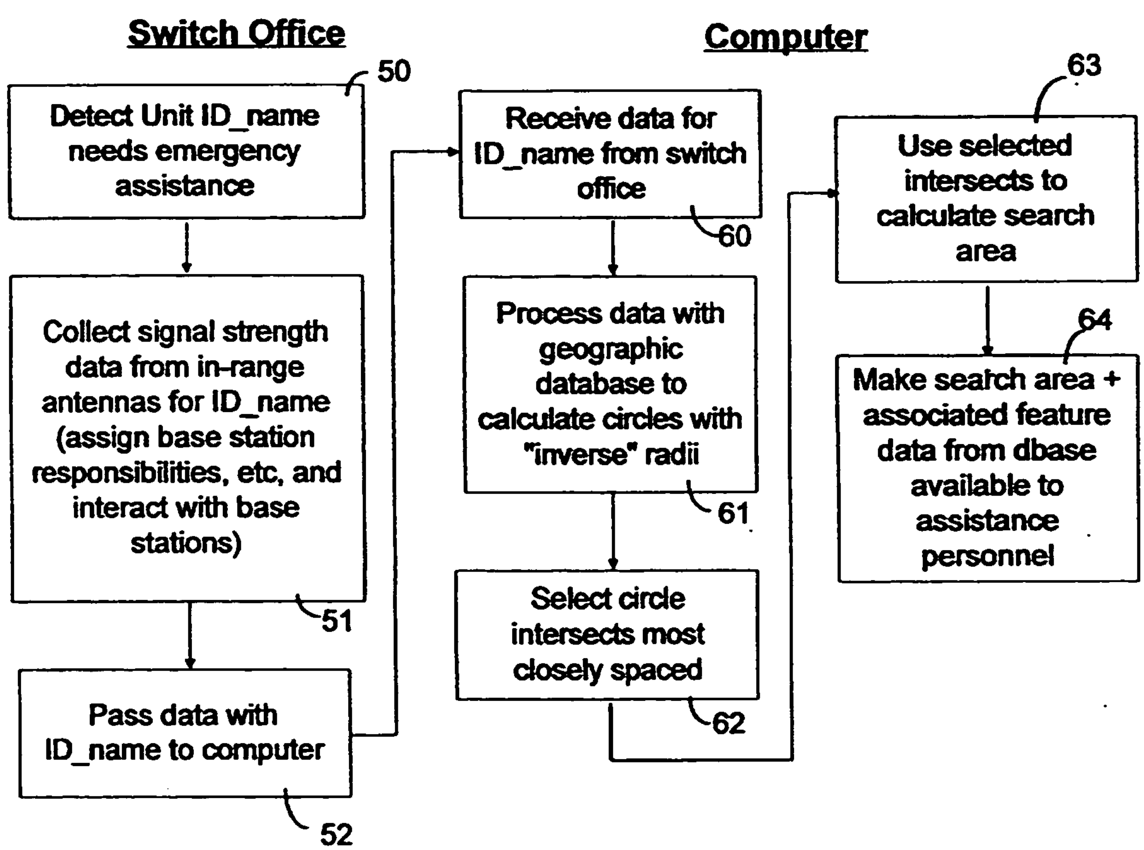


Fig. 6



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LOCATING MOBILE UNITS

The present invention relates to determining the location of wireless mobile units within a network, and is of particular relevance if the determination of the location of a mobile unit is to be made during an emergency call received from the unit.

In the reception and handling of emergency telephone calls (in the US termed 911 calls, in the UK termed 999 calls), it is important to be able to automatically pinpoint the location of a caller; e.g. an anxious or hysterical caller unable to tell his or her location, or a caller that does not know his/her location and has no visible landmarks that could be used to fully identify such. In calls over ordinary telephone sets directly linked by wire to the Public Switched Telephone Network (hereafter, PSTN), it is possible to trace the number of the telephone from which the call is placed and use that information to locate the caller, since the calling device or unit is associated with a known "building" address from which the caller's location is easily implied or determinable.

However, this is not possible when the respective calling unit is mobile; e.g. a cellular telephone or a "2-way" pager. Mobile units of this kind generally link to the PSTN through a network of geographically dispersed antennas, base stations and switching offices. Although such units have an identity which is signalled during a call, that identity neither implies their physical location nor forms a basis for calculating it. Furthermore, even if the locations of the antennas and distances between them are known, that information per se does not form a basis for determining the location of a unit with which they are currently communicating.

The problem we are concerned with presently is that of obtaining sufficient information about approximate locations of mobile units involved in critical situations (999 calls, emissions from stolen vehicles, etc.), to enable operators on the PSTN to dispatch personnel (rescue workers, firemen, policemen, etc.) with a fair probability of the latter being able to successfully locate respective units. Another problem we are concerned with here is that of providing the foregoing services in a cost-effective manner which places minimal burdens (financial or other) on users of otherwise inexpensive mobile units.

Prior art GPS (Global Positioning System) arrangements are known wherein mobile units involved in public emergency (999) call situations can establish their geographic locations and relay that information to public emergency operators/centers. However, such mobile units require complex radio links to earth satellites, and therefore tend to be too expensive to be used by more than a very small percentage of users involved in such situations.

Other known prior art describes techniques for determining approximate locations of mobile units wherein the determination is made wholly within the existing infrastructure serving such units and requires minimal information from the units themselves. However, this art does not concern itself with application of respective techniques to location of callers involved in emergency situations, and their levels of accuracy are considered too low to have useful application to more than a very small percentage of emergency call situations involving mobile units.

Accordingly, the invention provides a method of determining the location of a mobile unit in a network comprising multiple antennas, comprising the steps of:

receiving a signal from said mobile unit at two or more of said multiple antennas; for each of said two or more antennas, determining the strength of the received signal, and deriving a provisional location estimate based on said signal strength; and deriving a combined location estimate based on the intersection of the provisional location estimates from said two or more antennas.

In the preferred embodiment, multiple antennas are linked via network base stations to at least one network switching office, and a computer system linked to said at least one network switching office is used to derive said provisional location estimate, and to derive said combined location estimate. Mapping information is stored at said computer system, and information related to said combined location is retrieved responsive to deriving said combined location.

Such determination of location is particularly beneficial in conjunction with the operation of an emergency assistance centre to respond to a call from a mobile unit. Thus the determined location estimate of the mobile unit can be passed by the computer to the operator handling the emergency call, along with any retrieved mapping information.

The present invention also provides a method for assisting in locating wireless mobile units in emergency situations within a telecommunication network serving said mobile units, said network including multiple antennas, multiple base stations each serving plural said antennas, and multiple switching offices each serving plural said base stations, said method comprising: storing within a computer system, shared by plural said switching offices, a geographic database including locations of all of the antennas served by all of the base stations served by said plural switching offices sharing said computer;

detecting at said switching offices and base stations that a specifically identifiable one of said mobile units communicating through antennas served by respective base stations requires emergency assistance; responsive to a detection that said identifiable mobile unit requires emergency assistance, and while the mobile unit is actively communicating through plural antennas served by one or more base stations, interacting with said one or more base stations to gather information about instantaneous strengths of signals being received by respective antennas from said identifiable unit; transferring said gathered information to said computer system; and utilizing said gathered signal strength information at said computer system in conjunction with said geographic database to calculate a geographic search area having a high probability of containing said identifiable unit.

Said search area should be of a size that would be subject to a practical search even if a user of said unit currently requiring emergency assistance is unable to provide further information about their specific geographic location.

In the preferred embodiment said database includes specific information about distinguishable physical objects within said searchable area, and the method further includes the step of the computer making this specific information available to personnel responsible for assisting in locating said identifiable unit. Also in the preferred embodiment, said database includes specific information as to geographic sites of cell antennas, and the calculation of the search area includes the steps of: constructing circles of different radii relative to sites of antennas currently in communication range of said identifiable unit, said circles having radii whose lengths are inversely related to signal strengths instantly being received at respective antennas from said identifiable unit; analyzing intersections of said constructed circles to locate a cluster of most closely spaced intersections; and using said

cluster of most closely spaced intersections to define the search area.

In one embodiment, said information about instantaneous strengths of signals being received by said respective antennas is augmented at least in part by other information indicative of distances between said respective antennas and said identifiable unit, said other information including information obtained by signalling interaction between said antennas and said unit wherein signals of varying strength are transmitted to said unit evoking responses indicative of respective said distances.

The method of the invention may also include the step of determining if a user of said identifiable unit has two different types of 2-way signalling units, and if so, augmenting signal strength determinations by utilizing communications with both of said two different types of signalling units for effecting said determinations.

Viewed from another aspect, the present invention provides, for a telecommunication network serving wireless mobile units -- said network including multiple antennas, multiple base stations each serving plural said antennas, and multiple switching offices each serving plural said base stations -- a system arrangement for assisting in locating said mobile units in emergency situations, said system arrangement comprising: means at said switching offices and base stations for detecting that a specifically identifiable one of said mobile units communicating through antennas served by respective base stations requires emergency assistance; a computer system shared by plural said switching offices; said computer system containing a geographic database including locations of all of the antennas served by all of the base stations served by said plural switching offices sharing said computer;

means at said plural switching offices sharing said computer system -- said means responsive to detection that a said identifiable one of said mobile units currently requires emergency assistance, while the respective unit is actively communicating through plural antennas served by plural base stations that in turn are served by said plural switching offices sharing said computer system -- for interacting with respective said plural base stations to gather information about instantaneous strengths of signals being received by respective said plural antennas from said unit currently requiring emergency assistance; said means for gathering said signal strength information including means for transferring said gathered information to said computer system; and

said computer system comprising means for utilizing said gathered signal strength information in conjunction with said geographic database for calculating a searchable geographic area having a high probability of containing said unit currently requiring emergency assistance; said searchable area being of a size that would be subject to a practical search even if a user of said unit currently requiring emergency assistance is unable to provide information about their specific geographic location.

Viewed from yet another aspect, the invention provides in a telecommunication network serving wireless mobile units employed by a significant percentage of the general population, a method of locating a unit whose user requires emergency assistance comprising:

using mainly existing infrastructure of said network, and in a manner not requiring said user to have any equipment other than said unit as well as not requiring said user to have any specific information to aid in his or her location, calculating a searchable geographic area that is: (a) likely to include the location of said user; and (b) of a size small enough that it would be practical to search that entire searchable area if necessary to find said user in a reasonable time.

Thus a cost-effective technique is provided for determining approximate locations of mobile units, which has practical applications to public emergency calls and other critical situations involving virtually all users of such units, and which is not dependent for practicality upon having the users per se supply information relative to their locations.

In a preferred embodiment, approximate locations of existing (and future) mobile units involved in public emergency situations are determined in a fairly practical manner by using signal strength information detected within the communication infrastructure currently in communicating range of the calling unit, in combination with special database information included in computing equipment linked to the respective infrastructure. These infrastructures generally consist of radio antennas within listening range of a mobile unit originating a public emergency/999 call, base stations linked to those antennas, and switching offices linking the base stations with the PSTN.

The special database information referred to above includes relevant information about the region encompassed by each antenna;

particularly, defining highways, streets, mountains, rivers, building structures, etc., pertinent to each region. The signal strength information obtained from the in-range antennas and their base stations is used to calculate a small circular area in which the calling unit is believed to be located. Information describing that area is passed to the public emergency operator (or assistance center) via the PSTN, along with data extracted from the special database. Using the latter data emergency operators can interact with users of respective mobile units to ask questions about significant landmarks currently visible to those users (street signs, buildings, hotels, mountains, hills, streams, etc.), with responses to those questions greatly increasing the likelihood of locating respective users. The operators can then dispatch rescue (or other) workers to respective users with corresponding increased likelihood of the latter being able to quickly locate respective users.

In the initial handling of this process, network controllers, containing switching offices that interface between the PSTN and base stations within listening range of a mobile unit issuing a public emergency/999 call, interact with the base stations to determine strengths of signals received at the base stations from the respective mobile unit. This interaction involves assignment of primary tracking responsibility to one in-range station (usually, a station receiving a strongest signal, although current signal traffic and other circumstances may require that responsibility to be shifted elsewhere) and secondary tracking responsibilities to other in-range stations.

Base stations assigned these responsibilities individually monitor transmissions received by their associated antennas from the respective mobile unit, particularly seeking to detect identity (ID) signals, which are usually sent by the respective unit embedded within its transmissions, and strengths of such ID signals as received. As these ID's and their signal strengths are detected, messages are sent to the network controller, each message furnishing information identifying the receiving antenna, the mobile unit ID and the currently measured signal strength of that unit. In addition to performing these functions, the station having primary tracking responsibility passes all other signals received from the mobile unit to the switching office contained in the network controller for transmittal by that office to the PSTN.

The network controller, or its supporting computer, uses the information identifying participating antennas to ascertain locations of

respective antennas, and the signal strength information associated with those antennas to calculate a circular area in which the mobile unit is located. That area is much smaller than the area encompassed by any antenna, but possibly too large to be useful in a practical sense for locating the mobile caller. Using this area information, the database is accessed to extract geographic and other parameters, information and other data pertinent exclusively to that area. The area information and extracted data are then passed via the PSTN to the emergency assistance center. At the latter location, the extracted data can be used by assistance operators processing a public emergency call to ask specific questions of a caller about landmarks (hotels, signs, street names, etc.) and the like that the caller may currently be able to see or otherwise identify. Responses to these specific questions enable the operator(s) to considerably reduce the circular area to a smaller one in which there is a high probability that dispatched personnel would quickly find (and help) the caller.

The size of the circular area initially established from the signal strength measurements, and therefore the intrinsic pertinence of that information to the user's actual location, depends on a number of factors; for example, the number of antennas and base stations participating in the process, weather conditions present during the call, etc. Nevertheless, in many instances, this information per se could be useful to enable dispatched personnel (rescue workers, police, etc.) to locate the calling unit and its user. Furthermore, if the calling party is able to provide relevant information in response to specific questions asked by a public emergency operator (e.g. noticeable landmarks, street signs, etc.), that information should be useful to determine a smaller area, within the originally calculated circular area, in which the caller is probably located.

An important advantage of this system is that it makes extensive use of existing mobile communication infrastructures associated with extensively used mobile units, and therefore provides cost effective emergency location service to a large number of potential users. Another advantage is that it does not require either the caller or the public assistance operator receiving the call to have special hardware or software.

The database used for extracting parameters relevant to an initially calculated circular area should include information available

from regional maps and additional information identifying geographic locations of specific landmarks, buildings, and other topographical structures within each mapped region.

Furthermore, if the tracking network uses currently new "steerable" antennas, rather than the omnidirectional antennas commonly used in existing mobile systems, the accuracy of location with presently defined techniques could be greatly increased.

Other features of wireless systems could also be used to improve accuracy. For example, most existing mobile units (both for telephone speech and 2-way paging) have a constantly active "command" channel (one that is "on" as long as the unit is powered on). That channel is useful for tracking as the user roams (e.g. moves between regions receiving primary coverage from different antennas). Information obtained through monitoring this channel can be used to add accuracy to the present position location functions. Furthermore, it would not be too difficult to modify mobile units utilizing such command channels to be able to report to the supporting infrastructure information about the strength of signals currently being received at the calling unit, and thereby additionally enhance the accuracy of present circular area calculations.

Another contemplated variation or addition is to adapt the existing infrastructure to be able to send out certain signals of progressively decreasing strengths and have the mobile unit receiving such signals feed back information about their received strength up to the point at which contact is lost. This information could be used to calculate a location radius relative to the respective antenna and could further improve the accuracy of calculation of the circular area supposedly containing the caller's unit.

In addition to use in public emergency situations, some of the present techniques could be used to fix locations of stolen objects (e.g. automobiles) containing radio transmitters.

Additionally, using above-characterized circular area calculations, network controllers participating in the tracking process can be required to route an emergency call to an emergency center convenient to the most likely location of the caller, using call routing rules fixed locally.

Additionally, callers possessing more than one calling device (e.g.

a cellular phone and 2-way pager) could be requested to operate both devices, and information obtained from both (i.e. with different ID's) could be correlated to improve location results.

An embodiment of the invention will now be described in detail by way of example only with reference to the following drawings:

Figure 1 is an overview of a mobile communication network;

Figure 2 shows a typical antenna coverage pattern, for handling communications relative to mobile cellular phone units, with a single mobile unit shown at a selected site;

Figure 3 shows the same Figure 2 with the mobile unit shown at another site representing a "worst case" situation for emergency location;

Figure 4 illustrates a portion of the pattern of Figure 2 together with circles forming the basis for calculating a "small" area containing the site of the respective mobile unit as shown in Figure 2; and

Figure 5 illustrates a portion of the pattern of Figure 3 together with circles forming the basis for calculating a "small" area containing the site of the respective mobile unit as shown in Figure 3.

1. **Overview of Present System**

Figure 1 provides an overview of a mobile communication network configured in accordance with this invention. Mobile wireless unit 1 (e.g. a cellular phone) links to two or more antennas 2, 3 within its listening range (two antennas are shown for simplicity, but it is understood that more of such may be within range). The antennas link to a base station 4 that typically may serve both these (in-range) antennas and other antennas. Each base station such as 4 links to a switching office 5 which may serve additional base stations. Switching office 5 includes a switching section 5a and a network control section 5b. Switching section 5a provides switched connections between base stations and the PSTN (public switched telephone network), the latter shown at 6. Network control section 5b controls section 5a and operating states of base stations such as 2, 3. PSTN 6 provides connections between base stations served by section 5a and telephones within the PSTN, including telephones located at public emergency assistance centers shown at 7 and 8.

Switching office 5 also links to computer 9 having a special database 10 for emergency assistance usage. Computer 9 and its database

10 may be shared by multiple switching offices such as 5.

It should be understood that the network shown in part in Figure 1 generally would contain more antennas than base stations, more base stations than switching offices, and more switching offices than shared computers such as 9. Thus, use of computers such as 9 and respective databases such as 10 meets present objectives of providing cost-effective emergency assistance with minimal additions to infrastructures of existing wireless mobile communication networks and with minimal expense to users of mobile wireless units utilizing such networks.

There are at least two channels of communication between each office such as 5 and each associated base station such as 4. These include a "data" channel 11, for transferring voice and/or data signals directly between the base station and switching section 5a, and a "control" channel 12 for transferring command and control signals between the base station and network control section 5b. Since each office such as 5 may serve plural base stations, additional data and control channel links to other base stations are suggested respectively at 13 and 14. There are also at least two channels of communication between each office 5 and the shared computer such as 9; including a data channel 16 between switching section 5a and the computer and a control channel 17 between network control section 5b and the computer.

Each antenna 2, 3 provides communication coverage over a surrounding cellular region. The coverage is usually omnidirectional so a typical cellular region would have circular form (or some partially circular form if there are mountains or other obstructions within the antenna's range). Typical layouts of circular cellular regions are indicated in Figures 2 and 3 discussed below, wherein individual cell regions are labelled CRi (i=1-7). Although these figures show the cell regions as symmetrical and of equal size, it is understood that in general the region shapes and sizes could differ considerably depending upon geographic topology, etc. Further, although the cells are shown here as contiguous for ease of illustration, in practice the cells overlap. Also, although the cells are shown by convention as symmetrical hexagons, in practice they can have other forms depending upon antenna designs and power radiated by them.

Initially, the cells are laid out and tested for area coverage based on terrain, interference (from buildings and other structures), and

quality of signal. These areas are carefully characterized by the network provider, and locations of antennas and associated transceiving equipment within each area are precisely determined and recorded. Based on these characteristics, and referring to Figure 2, it is known that a mobile unit located at position 20 in cellular region CR7, will be sensed by antennas in cellular regions CR7, CR5, CR6, and CR4; and in most cases the supporting network controller will assign primary responsibility for a call to or from that unit to the cell antenna in region CR7. Primary responsibility may be assigned to another cell within sensing range, depending upon traffic conditions and other factors. Primary responsibility refers to the handling of signals representing voice and/or data signals between an antenna and the switching section of a respective switching office via a respective base station. This handling of signals involves tracking identity signals embedded in all transmissions from the mobile unit that is being served. Cells not having primary responsibility, but within sensing range, usually ignore the transmitted ID signals. Such assignment of primary responsibility, regardless of how implemented, does not affect the operation of the present invention; and it is understood that such operation would also be unaffected by concurrent assignment of primary responsibility for one call to plural cells.

Two functions presently described for providing assistance in public emergencies involving mobile wireless units such as 1 are: 1) the ability to determine a small area in which the unit is probably located, preferably an area of sufficiently small size to conduct a practical search for locating the unit even if its user is unable to describe his or her location, and 2) the ability to provide the user with practical visual cues that may be useful for establishing a more precise location within that small area; for example, being able to question the user as to whether specific terrain, landmarks, building signs, and other structures are visible, and using the user's responses to such questions to narrow the area to be searched (for example a response that a suggested building sign is seen on one side and a suggested structure is seen on another side could be used to further pinpoint his/her location).

The following sections describe how the arrangement shown in Figure 1 provides these functions of determining a first small area and then providing potentially visible cues to reduce that area to a smaller one.

2. Determining Small Area in Which User/Unit is Located

When a call from a mobile unit involves an emergency situation or the like (e.g. the call is to a public 999 number), a network control 5b associated with antennas in sensing range of the respective unit (or several network controls if the in-range antennas are linked to several controls) assigns secondary tracking responsibilities to plural cells in sensing range of the calling unit. Antennas and base stations of cells having secondary tracking responsibilities monitor ID signals emitted from the mobile unit to be tracked, determine strengths of respective signals, and report respective findings in messages to respective network controls. Cells having primary responsibility perform these same functions and also relay signals representing voice and/or data between the respective unit and the switching section of the respective switching office for transferral to an appropriate emergency assistance center via the PSTN.

Thus, if the unit at position 20 in Figure 2 is involved in an emergency call, primary tracking responsibility could be assigned to CR7 (the cell receiving the strongest signal from the unit and therefore nearest to the unit), and secondary tracking responsibilities could be assigned to CR5, CR6, and CR4 (cells receiving weaker signals but within sensing range).

As each cell having primary or secondary tracking responsibility detects the ID signal of a unit calling for emergency assistance, the base station serving the cell determines the strength of the signal just received and forwards a message, preferably in digital form, to the respective network control; the message stating the caller ID and signal strength detected. A corresponding message is passed from the network controller to computer 9 for analysis. Using map information in its database, including precise locations of all antennas in sensing range, the computer calculates intersections of circles drawn about the sensing sites. These circles have different radii with lengths inversely proportioned to signal strengths reported from respective cells (i.e. the circle drawn for the cell reporting the highest signal strength having the smallest radius and the circle drawn for the cell reporting the lowest signal strength having the largest radius). Choosing a space having the highest density of intersections of these circles, the computer determines a small area to search with a high probability of that area containing the actual site of the calling unit. The selected area is sufficiently small to be subject to a practical search having a high likelihood of quickly locating the caller, assuming the caller is

completely unable to describe his/her location.

Circles calculated relative to the cellular coverage pattern of Figure 2, with an emergency caller actually located at position 20 in that figure, are illustrated in Figure 4. Circles calculated relative to the same coverage pattern as shown in Figure 3, wherein the caller is actually situated at a "worst case" position 21, are shown in Figure 5.

For the caller situation of Figures 2 and 4, the circle calculated for the strongest signal, that reported from CR7, is a small circle 30 wholly contained within region CR7. In the same situation, the circle calculated from the weaker signals reported from CR6, CR4, and CR5 -- respectively shown at 31, 32 and 33 -- have larger radii than circle 30. Examining Figure 4 closely reveals that these circles have at least 5 intersections clustered close to each other within CR7 and several widely separated intersections located outside CR7 (one in CR4 and two outside all of the in-range regions). It is readily apparent that the cluster of closely spaced intersections is very near to the actual calling site 20 ("very near" in this context meaning at a distance that is very small by comparison to the distances between centers of adjacent cells). Thus, by drawing a small circle containing and slightly larger than the space occupied by the cluster, an area is formed that is both very likely to contain the calling unit and small enough to be quickly searched (e.g. by rescue personnel dispatched to the respective call) with a highly likelihood of having the caller located even if the caller is unable to assist in his/her location.

In the "worst case" situation of Figure 3, the actual location 21 of the calling unit is within CR7, but approximately equidistant from CR5 and CR6, and out of range of CR4. Thus, fewer circles and circular intersections are formed -- 40, 41 and 42, formed respectively relative to CR7, CR6 and CR5 -- giving the computer less data to work with in establishing an area subject to practical search. Nevertheless, in this configuration, the computer should find a cluster of three closely spaced intersections in CR7 below its center, two more intersections in CR7 above the center, and one intersection in CR4 (the latter derived from the circles drawn from signal strengths reported from CR5 and CR6). Proper analysis of this data would lead the computer to select a small area containing the cluster of three intersections as likely to be closest to the actual unit site. Similarly, selection of a small area surrounding this cluster is likely to provide an area encompassing the

caller's site that is practical to search.

In any of the foregoing situations, there is some small probability that the search area selected by the computer would not contain the actual call site, but in that circumstance there is a very high likelihood that the actual site is very close to the periphery of the selected area, and that the caller might still be quickly located in a practical search.

Upon selecting a "practical search area" the computer interacts with the respective switching office to communicate related information through the PSTN to the public emergency assistance center (7,8, Fig. 1) at which the respective call is being handled. The related information could for example be a street/road map of the selected area. Such a map would include significant topographic and geographic features of the respective area, and precise location of each feature in the area, as described next.

3. Prompting User With Specific Geographic and Other Cues

Upon selecting a suitable search area, the computer uses its database to determine easily recognizable geographic and topographic features of the selected area (e.g. rivers, hills, buildings, hotels, signs, billboards, gas stations, uniquely colored fences, etc.), and the precise location of each feature (e.g. coordinates thereof) within the respective area.

This information, together with information effectively constituting a map of the respective area (e.g. a street and building address map), is communicated via the PSTN to the emergency assistance center to which the call has been assigned.

With this information and map, an operator at the emergency assistance center could question the (emergency) caller as to locations of specific features relative to the caller's current location: e.g. "can you see a XYZ company gas station and a billboard from where you are located". If the caller responds affirmatively to any question the position of the caller could then be either precisely determined or at least narrowed to within a very small and specific sub-area of the selected search area. If the caller is unable to identify any feature, the operator could still immediately dispatch rescue personnel with

instructions to search the entire selected area; describing boundaries of the selected area to them or telecommunicating the information received from the computer to them.

4. Variations and Enhancements

If the network serving the mobile units contains or is modified to contain steerable antennas, having sensing patterns covering more precisely definable linear areas, the computer could determine precise vector locations getting much closer to the actual calling site, rather than relying on selection of clustered circular intersections. In addition, knowledge of which antennas are unable to receive a signal could also be used to determine user location (by providing a zone of exclusion).

Most wireless units, both cellular phones and pager units, have a command channel that is on or active while the respective unit is active. This feature can be used to enhance the present location determining functions by adapting the command channel to report back strengths of signals currently received in that channel, enabling the computer to more precisely establish the search area. As a further alternative, the antennas could be controlled during appropriate short intervals to provide signals of progressively decreasing strength through this channel, and the units then modified to report back a specific phase in the decrease sequence at which loss of contact occurs. With this type of interaction, the approximate distances between a caller and individual antennas could be determined with greater precision.

Another possibility is that although in the described embodiment, the computer simply uses a linear relationship between signal strength and distance from the base station in order to derive the possible location from signal strength, a wide variety of alternative techniques might be used. For example, the computer may store a contour map of received signal strength against location, from earlier survey work, or may try to model signal reception at a location based on stored topographical information, and so on.

Techniques described above for locating emergency callers could readily be modified to locate equipment involved in other situations; for instance, to locate a stolen object such as an automobile carrying a radio which emits signals trackable by appropriately distributed

antennas.

Additionally, if the location of the emergency caller can be precisely defined by the calling unit or its user, and if that location is within range of several emergency assistance centers, the call can be routed to one appropriate center based on local rules established between the centers and the mobile switching offices.

Also, if a caller possesses more than one type of mobile unit, e.g. a cellular phone and pager, both units could be activated and tracked and resulting data correlated to establish a more precise basis for calculating a suitable search area.

CLAIMS

1. A method of determining the location of a mobile unit in a network comprising multiple antennas, comprising the steps of:

receiving a signal from said mobile unit at two or more of said multiple antennas;

for each of said two or more antennas, determining the strength of the received signal, and deriving a provisional location estimate based on said signal strength;

and deriving a combined location estimate based on the intersection of the provisional location estimates from said two or more antennas.

2. The method of claim 1, wherein said multiple antennas are linked via network base stations to at least one network switching office, and wherein a computer system linked to said at least one network switching office is used to derive said provisional location estimate, and to derive said combined location estimate.

3. The method of claim 2, further comprising the steps of:

storing mapping information at said computer system;

and responsive to deriving said combined location, retrieving stored mapping information related to said combined location.

4. A method of operating an emergency assistance centre to respond to a call from a mobile unit, comprising the steps of:

determining the combined location estimate of the mobile unit according to any preceding claim; and

providing the combined location estimate to the operator handling the emergency call.

5. A method of operating an emergency assistance centre to respond to a call from a mobile unit, comprising the steps of:

determining the combined location estimate of the mobile unit according to claims 3; and

providing the combined location estimate and retrieved mapping information to the operator handling the emergency call.

6. A method for assisting in locating wireless mobile units in emergency situations within a telecommunication network serving said mobile units, said network including multiple antennas, multiple base stations each serving plural said antennas, and multiple switching

offices each serving plural said base stations, said method comprising:

storing within a computer system, shared by plural said switching offices, a geographic database including locations of all of the antennas served by all of the base stations served by said plural switching offices sharing said computer;

detecting at said switching offices and base stations that a specifically identifiable one of said mobile units communicating through antennas served by respective base stations requires emergency assistance;

responsive to a detection that said identifiable mobile unit requires emergency assistance, and while the mobile unit is actively communicating through plural antennas served by one or more base stations, interacting with said one or more base stations to gather information about instantaneous strengths of signals being received by respective antennas from said identifiable unit;

transferring said gathered information to said computer system; and

utilizing said gathered signal strength information at said computer system in conjunction with said geographic database to calculate a geographic search area having a high probability of containing said identifiable unit.

7. The method of claim 6, wherein said search area is of a size that would be subject to a practical search even if a user of said unit currently requiring emergency assistance is unable to provide further information about their specific geographic location.

8. The method of claim 6 or 7, wherein said database includes specific information about distinguishable physical objects within said searchable area, and wherein the method further includes the step of the computer making this specific information available to personnel responsible for assisting in locating said identifiable unit.

9. The method of claim 6, 7 or 8, wherein said database includes specific information as to geographic sites of cell antennas, and the calculation of the search area includes the steps of:

constructing circles of different radii relative to sites of antennas currently in communication range of said identifiable unit, said circles having radii whose lengths are inversely related to signal strengths instantly being received at respective antennas from said identifiable unit;

analyzing intersections of said constructed circles to locate a

cluster of most closely spaced intersections; and

using said cluster of most closely spaced intersections to define the search area.

10. The method of any of claims 6 to 9, wherein said information about instantaneous strengths of signals being received by said respective antennas is augmented at least in part by other information indicative of distances between said respective antennas and said identifiable unit, said other information including information obtained by signalling interaction between said antennas and said unit wherein signals of varying strength are transmitted to said unit evoking responses indicative of respective said distances.

11. The method of any of claims 6 to 10, further including the step of determining if a user of said identifiable unit has two different types of 2-way signalling units, and if so, augmenting signal strength determinations by utilizing communications with both of said two different types of signalling units for effecting said determinations.

The Patent Office

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G4H (HNEE), H4D (DPAX, DPX), H4L (LDSL)

Int Cl (Ed.6): B60R 25/10, G01S 5/14, G08B 25/01, H04Q 7/38

Other: Online database: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2280327 A	(NEC) p.5 lines 8 - 29 & p.7 line 21 - p.8 line 2	1, 2
X	EP0133378 A2	(122923 CANADA) p.6 line 9 - p.7 line 6	1, 2
X, P	WO96/31076 A1	(ERICSSON) p.9 line 24 - p.14 line 7	1-3
X	WO96/04155 A1	(TRACKMOBILE) p.13 line 1 - p.25 line 11	1-9
X	US5515285	(GARRET) col.15 line 18 - 45	1-9
X	US5390339	(BRUCKERT) col.3 line 1 - col.5 line 11	1, 2
X	US5218367	(SHEFFER) col.6 line 26 - col.9 line 50	1-9

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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